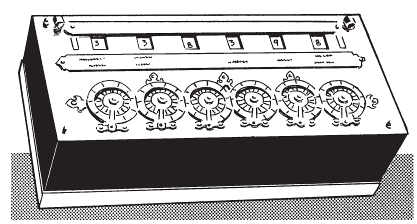
This chapter discusses the history of computers and how computers process and store data. High-level programming languages, networks, object-oriented programming, and important social and ethical issues relating to computers are also discussed.

1.1 Mechanical Devices

Pascaline

One of the earliest mechanical calculating devices was the *Pascaline*, invented in 1642 by the French philosopher and mathematician Blaise Pascal. The Pascaline was a complicated set of gears that operated similarly to a clock. It was designed to only perform addition. Unfortunately, due to manufacturing problems, Pascal never got the device to work properly.

Blaise Pascal
1623 – 1662

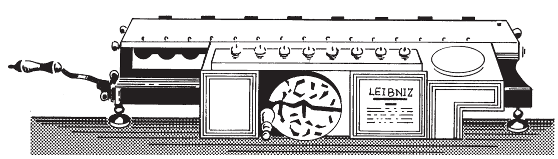


The Pascaline was a mechanical calculating device invented by Blaise Pascal in 1642

Stepped Reckoner

Later in the 17th century Gottfried Wilhelm von Leibniz, a famous mathematician, invented a device that was supposed to be able to add and subtract, as well as multiply, divide, and calculate square roots. His device, the *Stepped Reckoner*, included a cylindrical wheel called the *Leibniz wheel* and a moveable carriage that was used to enter the number of digits in the multiplicand. However, because of mechanically unreliable parts, the device tended to jam and malfunction.

Gottfried Wilhelm von Leibniz
1646 – 1716



The Stepped Reckoner was another early attempt at creating a mechanical calculating device

Difference Engine

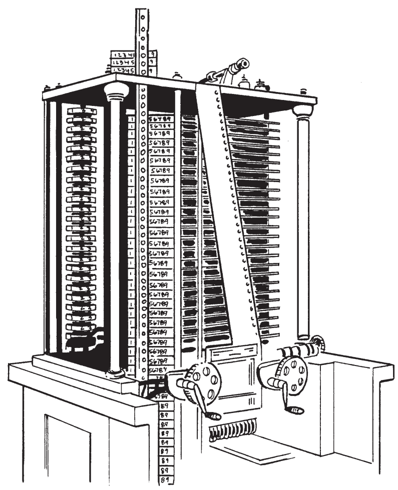
In 1822 Charles Babbage began work on the *Difference Engine*. His hope was that this device would calculate numbers to the 20th place and then print them at 44 digits per minute. The original purpose of this machine was to produce tables of numbers that would be used by ships' navigators. At the time, navigation tables were often highly inaccurate due to calculation errors and a number of ships were known to have been lost at sea because of these errors. Although never built, the ideas for the Difference Engine led to the design of Babbage's Analytical Engine.

Analytical Engine

The *Analytical Engine*, designed around 1833, was supposed to perform a variety of calculations by following a set of instructions, or program, stored on punched cards. During processing, the Analytical Engine was planned to store information in a memory unit that would allow it to make decisions and then carry out instructions based on those decisions. For example, when comparing two numbers, it could be programmed to determine which was larger and then follow an appropriate set of instructions. The Analytical Engine was also never built, but its design served as a model for the modern computer.

The History of Punched Cards

Punched cards were originally used to provide instructions for weaving looms. In 1810 Joseph Jacquard, a French weaver, placed punched cards in his looms so that as the cards passed through the loom in sequence, needles passed through the holes and picked up threads of the correct color or texture.



Babbage's Analytical Engine was designed as a calculating machine that used punched cards to store information

Charles Babbage
1792 – 1871

Ada Byron
1815 – 1852

Babbage's chief collaborator on the Analytical Engine was Ada Byron, Countess of Lovelace, the daughter of Lord Byron. Interested in mathematics, Lady Byron was a sponsor of the Analytical Engine and one of the first people to realize its power and significance. She also wrote of its achievements in order to gain support for it. Ada Byron is often called the first programmer because she wrote a program based on the design of the Analytical Engine.

Babbage had hoped that the Analytical Engine would be able to think. Ada Byron, however, said that the Engine could never "originate anything," meaning that she did not believe that a machine, no matter how powerful, could think. To this day her statement about computing machines remains true.

1.2 Electro-Mechanical Devices

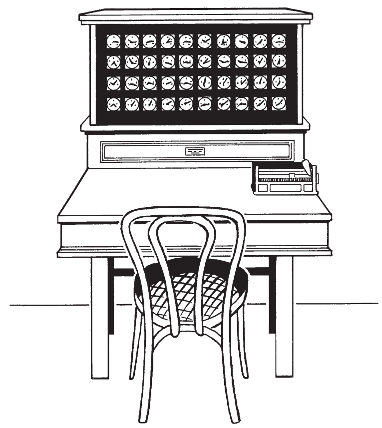
By the end of the 19th century, U.S. Census officials were concerned about the time it took to tabulate the continuously increasing number of Americans. This counting was done every 10 years, as required by the Constitution. However, the Census of 1880 took nine years to compile which made the figures out of date by the time they were published.

Hollerith's tabulating machine

In response to a contest sponsored by the U.S. Census Bureau, Herman Hollerith invented a tabulating machine that used electricity rather than mechanical gears. Holes representing information to be tabulated were punched in cards, with the location of each hole representing a specific piece of information (male, female, age, etc.). The cards were then inserted into the machine and metal pins used to open and close electrical circuits. If a circuit was closed, a counter was increased by one.

Herman Hollerith
1860 – 1929

Based on the success of his tabulating machine, Herman Hollerith started the Tabulating Machine Company in 1896. In 1924, the company was taken over by International Business Machines (IBM).



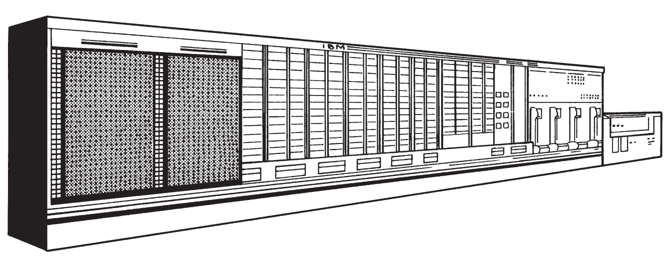
Herman Hollerith's tabulating machine, invented for the Census of 1890, used electricity instead of gears to perform calculations

Hollerith's machine was immensely successful. The general count of the population, then 63 million, took only six weeks to calculate. Although the full statistical analysis took seven years, it was still an improvement over the nine years it took to compile the previous census.

Mark I

In 1944, the *Mark I* was completed by a team from International Business Machines (IBM) and Harvard University under the leadership of Howard Aiken. The Mark I used mechanical telephone relay switches to store information and accepted data on punched cards. Because it could not make decisions about the data it processed, the Mark I was not a computer but instead a highly sophisticated calculator. Nevertheless, it was impressive in size, measuring over 51 feet in length and weighing 5 tons. It also had over 750,000 parts, many of them moving mechanical parts which made the Mark I not only huge but unreliable.

Howard Aiken
1900 – 1973



The Mark 1 was over 51 feet long and weighed over 5 tons

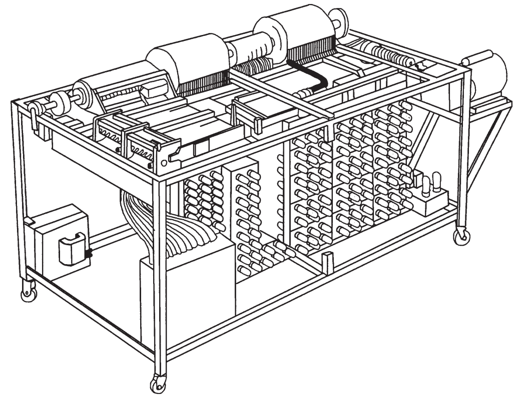
1.3 First Generation Computers

Atanasoff-Berry Computer

The first electronic computer was built between 1939 and 1942 at Iowa State University by John Atanasoff, a math and physics professor, and Clifford Berry, a graduate student. The *Atanasoff-Berry Computer* (ABC) used the binary number system of 1s and 0s that is still used in computers today. It contained hundreds of vacuum tubes and stored numbers for calculations by electronically burning holes in sheets of paper. The output of calculations was displayed on an odometer type of device.

John Atanasoff
1903 – 1995

Clifford Berry
1918 – 1963



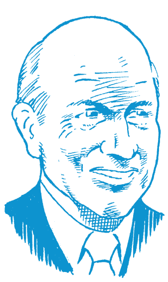
The Atanasoff-Berry Computer used the binary number system used in computers today

The patent application for the ABC was not handled properly, and it was not until almost 50 years later that Atanasoff received full credit for his invention. In 1990, he was awarded the Presidential Medal of Technology for his pioneering work. A working replica of the ABC was unveiled at the Smithsonian in Washington, D.C. on October 9, 1997.

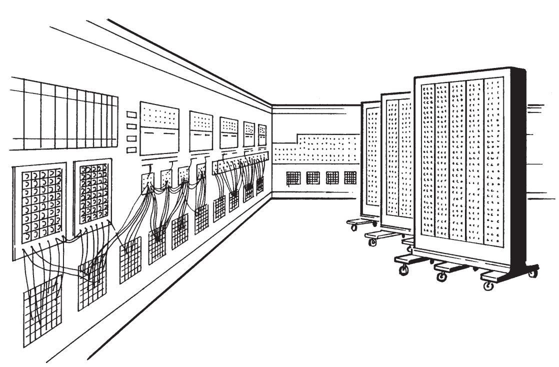
ENIAC

In June 1943, John Mauchly and J. Presper Eckert began work on the *ENIAC* (Electronic Numerical Integration and Calculator). It was originally a secret military project which began during World War II to calculate the trajectory of artillery shells. Built at the University of Pennsylvania, it was not finished until 1946, after the war had ended. But the great effort put into the ENIAC was not wasted. In one of its first demonstrations, ENIAC was given a problem that would have taken a team of mathematicians three days to solve. It solved the problem in twenty seconds.

John Mauchly
1907 – 1980



J. Presper Eckert
1919 – 1995



The ENIAC was originally a secret military project

The ENIAC weighed 30 tons and occupied 1500 square feet, the same area taken up by the average three bedroom house. It contained over 17,000 vacuum tubes, which consumed huge amounts of electricity and produced a tremendous amount of heat requiring special fans to cool the room.

computer

The ABC and the ENIAC are first generation computers because they mark the beginning of the computer era. A *computer* is an electronic machine that accepts data, processes it according to instructions, and provides the results as new data. Most importantly, a computer can make simple decisions and comparisons.

1.4 The Stored Program Computer

Alan Turing
1912 – 1954

The ABC and ENIAC required wire pulling, replugging, and switch flipping to change their instructions. A breakthrough in the architectural design of first generation computers came as a result of separate publications by Alan Turing and John von Neumann, both mathematicians with the idea of the stored program.

program

In the late 30s and 40s, Alan Turing developed the idea of a "universal machine." He envisioned a computer that could perform many different tasks by simply changing a program rather than by changing electronic components. A *program* is a list of instructions written in a special language that the computer understands.

John
von Neumann
1903 – 1957

CPU

In 1945, John von Neumann presented his idea of the stored program concept. The stored program computer would store computer instructions in a *CPU* (Central Processing Unit). The CPU consisted of different elements used to control all the functions of the computer electronically so that it would not be necessary to flip switches or pull wires to change instructions.

EDVAC
EDSAC
machine language

Together with Mauchly and Eckert, von Neumann designed and built the *EDVAC* (Electronic Discrete Variable Automatic Computer) and the *EDSAC* (Electronic Delay Storage Automatic Computer). These computers were designed to solve many different problems by simply entering new instructions that were stored on paper tape. The instructions were in *machine language*, which consists of 0s and 1s to represent the status of a switch (0 for off and 1 for on).

UNIVAC
C-10

The third computer to employ the stored program concept was the *UNIVAC* (UNIVersal Automatic Computer) built by Mauchly and Eckert. With the UNIVAC came the first computer language called *C-10*, which was developed by Betty Holberton. Holberton also designed the first computer keyboard and numeric keypad in an effort to make the computer more user-friendly. The first UNIVAC was sold to the U.S. Census Bureau in 1951.

Francis "Betty"
Holberton
1917 – 2001

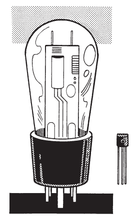
These first generation computers continued to use many vacuum tubes which made them large and expensive. They were so expensive to purchase and run that only the largest corporations and the U.S. government could afford them. Their ability to perform up to 1,000 calculations per second, however, made them popular.

1.5 Second Generation Computers

transistor

In 1947, William Shockley, John Bardeen, and Walter Brittain of Bell Laboratories invented the *transistor*. The invention of the transistor made computers smaller and less expensive and increased calculating speeds to up to 10,000 calculations per second.

John Bardeen, William Shockley, and Walter Brittain



One transistor (on right) replaced many tubes, making computers smaller, less expensive, and more reliable

Model 650

In the early 1960s, IBM introduced the first medium-sized computer named the *Model 650*. It was expensive, but much smaller than first generation computers and still capable of handling the flood of paperwork produced by many government agencies and businesses. Such organizations provided a ready market for the 650, making it popular in spite of its cost.

read, write

Second generation computers also saw a change in the way data was stored. Punched cards were replaced by magnetic tape and high speed reel-to-reel tape machines. Using magnetic tape gave computers the ability to *read* (access) and *write* (store) data quickly and reliably.

1.6 High-Level Programming Languages

Second generation computers had more capabilities than first generation computers and were more widely used by businesses. This led to the need for *high-level programming languages* that had English-like instructions and were easier to use than machine language. In 1957, John Backus and a team of researchers completed *Fortran*, a high-level programming language with intuitive commands such as READ and WRITE.

Grace Murray Hopper
1906 – 1992

Rear Admiral Dr. Grace Murray Hopper is also known for using the term "debug" for a programming error. A program running on the Mark II had to be "debugged" when a moth flew into the computer's circuitry causing an electrical short.

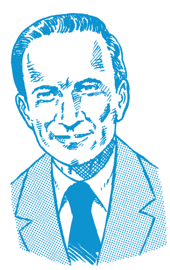
One of the most widely used high-level programming languages has been COBOL, designed by Grace Murray Hopper, a Commodore in the Navy at the time. *COBOL* (COmmon Business Oriented Language) was first developed by the United States Department of Defense (DOD) in 1959 to provide a common language for use on all computers. In the late 1970s, the DOD also developed Ada, named after the first programmer, Ada Byron. *Ada* is a high-level programming language that supports real-time applications. Large systems that rely on real-time processing, such as those used in the banking industry, often use Ada.

In the 1960s, John Kemeny and Thomas Kurtz developed BASIC at Dartmouth University. *BASIC* (Beginner's All-Purpose Symbolic Instruction Code) was widely used to teach programming to students during the 1970s. In the mid 1970s, *C* was developed by Dennis Ritchie at Bell Laboratories. C has been used to write a variety of applications.

object-oriented programming

In the 1980s, object-oriented programming (OOP) evolved out of the need to better develop complex programs in a systematic, organized approach. The OOP approach allows programmers to create modules that can be used over and over again in a variety of programs. These modules contain code called classes, which group related data and actions. Properly designed classes encapsulate data to hide the implementation details, are versatile enough to be extended through inheritance, and give the programmer options through polymorphism. Object-oriented languages include C++ and Java. Visual Basic .NET, released in 2002, has many features for easily developing an object-oriented program.

1.7 Third Generation Computers

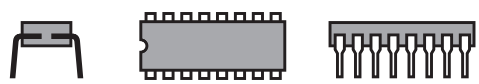


Robert Noyce
1927 – 1990

Noyce developed the integrated circuit while working for Fairchild Semiconductor. In 1968, he left Fairchild to form the company now known as Intel Corporation.

The replacement of transistors by integrated circuits (IC) began the third generation of computers. In 1961, Jack Kilby and Robert Noyce, working independently, developed the IC, also called a *chip*. One IC could replace hundreds of transistors, giving computers tremendous speed to process information at a rate of millions of calculations per second.

ICs are silicon wafers with intricate circuits etched into their surfaces and then coated with a metallic oxide that fills in the etched circuit patterns. This enables the chips to conduct electricity along the many paths of their circuits. The silicon wafers are then housed in special plastic cases that have metal pins. The pins allow the chips to be plugged into circuit boards that have wiring printed on them.



A typical chip is about 1 cm wide by 2.5 cm long

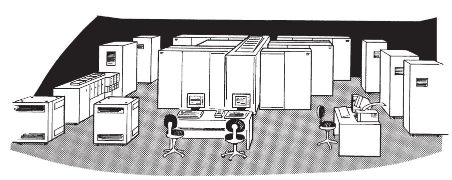
In 1964, the IBM *System 360* was one of the first computers to use integrated circuits and was so popular with businesses that IBM had difficulty keeping up with the demand. Computers had come down in size and price to such a point that smaller organizations such as universities and hospitals could now afford them.

Jack S. Kilby
1923 –

Kilby, working for Texas Instruments, developed the first integrated circuit. To demonstrate this new technology, he invented the first electronic hand-held calculator. It was small enough to fit in a coat pocket, yet as powerful as the large desktop models of the time.

1.8 Mainframes

A *mainframe* is a large computer system that is usually used for multi-user applications. They are used by large corporations, banks, government agencies, and universities. Mainframes can calculate a large payroll, keep the records for a bank, handle the reservations for an airline, or store student information for a university—tasks that require the storage and processing of huge amounts of information. The IBM System 360 was one of the first mainframes available.



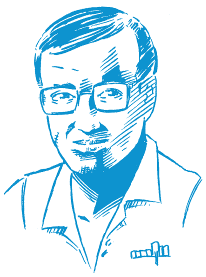
Mainframe computers are large and set up in their own rooms

Most people using mainframes communicate with them using *terminals*. A terminal consists of a keyboard for data input, and a monitor for viewing output. The terminal is connected by wires to the computer, which may be located on a different floor or a building a few blocks away. Some mainframes have hundreds of terminals attached.

1.9 Fourth Generation Computers

microprocessor

In 1970, Marcian Hoff, an engineer at Intel Corporation, invented the *microprocessor*, an entire CPU on a single chip. The replacement of several larger components by one microprocessor made possible the fourth generation of computers.



Marcian Hoff
1937 –

The small microprocessor made it possible to build a computer called a *microcomputer* or *personal computer* that fits on a desktop. The first of these was the Altair built in 1975. In 1976, Stephen Wozniak and Steven Jobs designed and built the first Apple computer. The Apple Macintosh set new standards for ease of computer use with its graphical user interface. In 1981, IBM introduced the IBM–PC. The computer was an instant success because of the availability of spreadsheet, accounting, and word processor software.

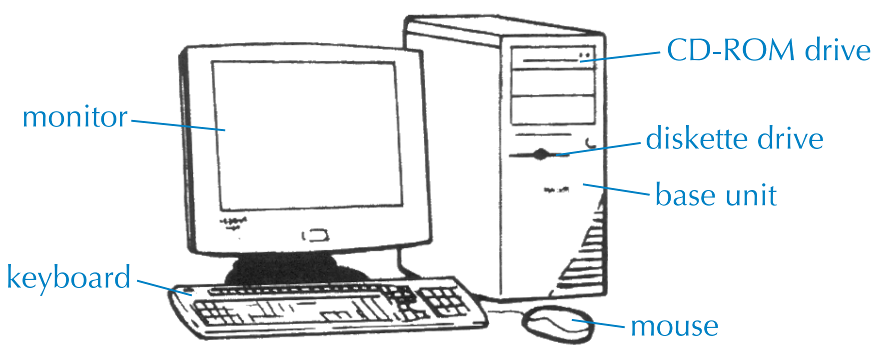
Stephen Wozniak
1950 –

Advances in technology made personal computers inexpensive and therefore available to many people. Because of these advances almost anyone could own a machine that had more computing power and was faster and more reliable than either the ENIAC or UNIVAC. As a comparison, if the cost of a sports car had dropped as quickly as that of a computer, a new Porsche would now cost about one dollar.

Steve Jobs
1955 –

1.10 The Personal Computer

The physical components of the personal computer, such as the monitor and base unit, are called *hardware*:



- The personal computer accepts data from an *input device*. Examples of input devices include the keyboard, mouse, CD/DVD drive, and disk drive.
- A personal computer becomes much more versatile when other devices such as printers and scanners are added. Such devices are sometimes called *peripheral devices*. A *scanner* is an input device that uses a laser to create a digital image from artwork such as photos and drawings. The digitized image can then be incorporated into a document.

Printers

A *laser printer* uses a laser and toner to generate characters and graphics on paper. An *ink jet* printer uses an ink cartridge to place very small dots of ink onto paper to create characters and graphics.

- *Output devices* display or store processed data. Monitors and printers are the most common visual output devices.

The *base unit* contains many components including a diskette drive, a CD/DVD drive, and a hard disk drive. The diskette and CD/DVD drives are accessible from outside the base unit, and the hard disk is completely contained inside the base unit.

The base unit also contains the *motherboard*, which is the main circuit board that contains the components:

- The **CPU** (Central Processing Unit) processes data and controls the flow of data between the computer's other units. Within the CPU is the **ALU** (Arithmetic Logic Unit), which can perform arithmetic and logic operations. It can also make comparisons, which is the basis of the computer's decision-making power. The ALU is so fast that the time needed to carry out a single addition is measured in *nanoseconds* (billionths of a second). The speed at which a CPU can execute instructions is determined by the computer's *clock rate*. The clock rate is measured in *megahertz* (million of cycles per second). A personal computer's clock rate could range from 450 MHz to 2.4 GHz.

nanoseconds

clock rate

- The personal computer's **memory** stores data electronically. **ROM** (Read Only Memory) contains the most basic operating instructions for the computer. The data in ROM is a permanent part of the computer and cannot be changed. **RAM** (Random Access Memory) is memory where data and instructions are stored temporarily. Data stored here can be changed or erased.
- Since RAM storage is temporary, data is stored on a type of *storage media*, such as a floppy diskette, a hard disk, a zip disk, or a CD-R. The base unit of most personal computers have

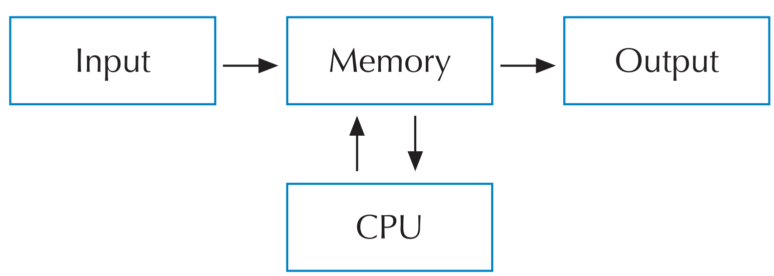
storage media

- **SRAM** (Static Random Access Memory) is high-speed memory referred to as cache (pronounced "cash"). This memory is used to store frequently used data so that it can be quickly retrieved by an application.
- A **bus** is a set of circuits that connect the CPU to other components. The **data bus** transfers data between the CPU, memory, and other hardware devices on the motherboard. The **address bus** carries memory addresses that indicate where the data is located and where the data should go. A **control bus** carries control signals.

How does the computer perform calculations?

How does the computer subtract, multiply, or divide numbers if the ALU can only perform arithmetic and compare numbers? The ALU does this by turning problems like multiplication and division into addition problems. This would seem to be a very inefficient way of doing things, but it works because the ALU calculates so fast. For example, to solve the problem 5×2, the computer adds five twos, $2 + 2 + 2 + 2 + 2$, to calculate the answer, 10.

The diagram below illustrates the direction that data flows between the separate components of a computer:



Notice that all information flows through the CPU. Because one of the tasks of the CPU is to control the order in which tasks are completed, it is often referred to as the "brain" of the computer. However, this comparison with the human brain has an important flaw. The CPU only executes tasks according to the instructions it has been given; it cannot think for itself.

software
operating system software
applications software

Personal computers also contain *software* that instructs the computer what to do. *Operating system software* is run automatically when the computer is turned on and enables the user to communicate with the computer by using input devices such as the mouse and keyboard. *Applications software* is written by programmers to perform a specific task, such as a word processor. Software is also called a program or an application.

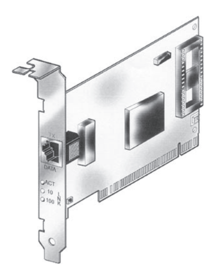
1.11 Networks

A *network* is a combination of software and hardware that works together to allow computers to exchange data and to share software and devices, such as printers. Networks are widely used by businesses, universities, and other organizations because a network:

- allows users to reliably share and exchange data
- can reduce costs by sharing devices such as printers
- can be set up to allow users access to only specific files
- simplifies the process of creating backup copies of files
- allows users to communicate with e-mail

Networks are classified by their size, architecture, and topology. One common size classification is *LAN* (Local-Area Network), which is a network used to connect devices within a small area such as a building or a campus. The *WAN* (Wide-Area Network) is used to connect computers over large geographical distances. A WAN can be one widespread network or it can be a number of LANs linked together.

The computers and other devices in a LAN contain a circuit board called a *network interface card*:



network interface card

A cable plugs into the network interface card to connect one device to another to form the LAN.

Wireless Networks

Wireless networks do not use cables. Instead they use high frequency radio waves or infrared signals to transmit data. WLANs (wireless local-area networks) are becoming more common as the cost decreases and performance improves.

Transmission Media

Computers must be connected in order to transmit data between the nodes. The type of connection used is called the *transmission media*.

Types of transmission media include twisted-pair wiring, coaxial cable, and fiber optic cable.

The amount of data and the speed at which the data can travel over the transmission media is called its *bandwidth* and is measured in bits per second (bps). Each type of transmission media has different length or range restrictions, data transmission rates, and costs.

network architecture

client/server

peer-to-peer

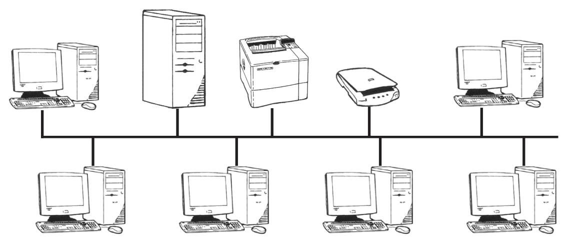
Network architecture includes the type of computers on the network and determines how network resources are handled. Two main types of network architecture are called client/server and peer-to-peer. A *client/server* network consists of a group of computers, called *clients*, connected to a server. A *server* is a powerful computer used to manage network functions such as communications and data sharing. A *peer-to-peer* network does not have a server. Each computer on the network is considered equal in terms of responsibilities and resource sharing.

topology

Topology is the logical arrangement of the nodes on a network. A *node* is a device, such as a computer or printer, that is connected to the network and is capable of communicating with other network devices.

bus topology

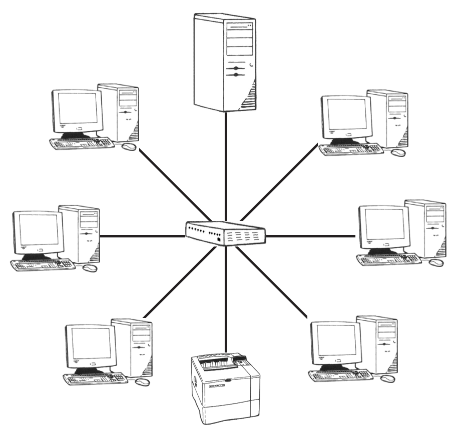
A popular LAN topology is the *bus topology* where each node is attached to a single shared communication cable that is often referred to as the bus:



LAN using a bus topology

star topology, hub

In a *star topology*, each node is attached to a *hub*, which is a device that joins communication lines at a central location on the network:



LAN using a star topology

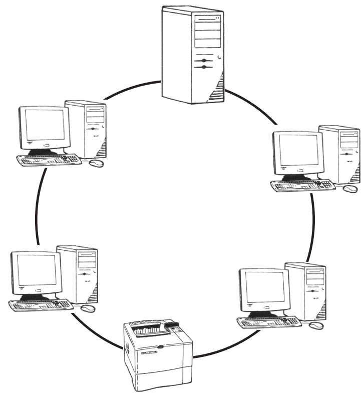
A *ring topology* connects each node to form a closed loop. Data travels in one direction and is sent from node to node, with each node examining the data and either accepting it or passing it on to the next node in the ring. A LAN with a ring topology can usually cover a greater distance than a bus or star topology:

Ethernet

One widely used LAN configuration, or protocol, is Ethernet, which was developed by Bob Metcalfe in 1976. This protocol significantly contributed to the growth of LANs in the late 1970s and 1980s. Ethernet uses a bus or star topology and connects the network devices by twisted-pair wiring, coaxial cable, or fiber optic cable. A newer version of Ethernet is Fast Ethernet, which operates at 100 Mbps and Gigabit Ethernet which operates at 1 Gbps (Gigabit per second).

Baseband and Broadband Technology

Most LANs use baseband technology which means the transmission media carries one signal at a time. Broadband technology allows for data transmission of more than one signal at a time. Broadband technology is found in WANs.



LAN using a ring topology

It is important to note that topology refers to the logical connection between the nodes and not the physical setup. For example, a ring topology may be set up in an arrangement other than a circle as long as the nodes form a closed loop.

1.12 Number Systems

binary number system

The electrical circuits on an IC have one of two states, off or on. Therefore, the *binary number system* (base 2), which uses only two digits (0 and 1), was adopted for use in computers. To represent numbers and letters, a code was developed with eight binary digits grouped together to represent a single number or letter. Each 0 or 1 in the binary code is called a *bit* (BInary digiT) and an 8-bit unit is called a *byte*.

bit, byte

base 10

Our most familiar number system is the decimal, or *base 10*, system. It uses ten digits: 0 through 9. Each place represents a power of ten, with the first place to the left of the decimal point representing 10^0, the next place representing 10^1, the next 10^2, and so on (remember that any number raised to the zero power is 1). In the decimal number 485, the 4 represents 4×10^2, the 8 represents 8×10^1, and the 5 represents 5×10^0. The number 485 represents the sum 4×100 + 8×10 + 5×1 (400 + 80 + 5) as shown below:

Decimal Number	Base 10 Equivalent
485	$4\times10^2 + 8\times10^1 + 5\times10^0 = 400 + 80 + 5$

base 2

The binary, or *base 2*, system works identically except that each place represents a power of two instead of a power of ten. For example, the binary number 101 represents the sum $1\times2^2 + 0\times2^1 + 1\times2^0$ or 5 in base ten. Some decimal numbers and their binary equivalents are shown below:

Decimal Number	Binary Number	Base 2 Equivalent		
0	0	$= 0\times2^1 + 0\times2^0$	= 0×2 + 0×1	= 0 + 0
1	1	$= 0\times2^1 + 1\times2^0$	= 0×2 + 1×1	= 0 + 1
2	10	$= 1\times2^1 + 0\times2^0$	= 1×2 + 0×1	= 2 + 0
3	11	$= 1\times2^1 + 1\times2^0$	= 1×2 + 1×1	= 2 + 1
4	100	$= 1\times2^2 + 0\times2^1 + 0\times2^0$	= 1×4 + 0×2 + 0×1	= 4 + 0 + 0

base 16

The hexadecimal system is used to represent groups of four binary digits. The *hexadecimal*, or *base 16*, system is based on 16 digits: 0 through 9, and the letters A through F representing 10 through 15 respectively. Each place represents a power of sixteen. For example, the hexadecimal number 1F represents the sum $1{\times}16^1 + 15{\times}16^0$. Some decimal numbers and their hexadecimal equivalents are shown below:

Decimal Number	Binary Number	Hexadecimal Number	Base 16 Equivalent		
0	0000 0000	0	$= 0{\times}16^0$	$= 0{\times}1$	$= 0$
10	0000 1010	A	$= 10{\times}16^0$	$= 10{\times}1$	$= 10$
15	0000 1111	F	$= 15{\times}16^0$	$= 15{\times}1$	$= 15$
20	0001 0100	14	$= 1{\times}16^1 + 4{\times}16^0$	$= 1{\times}16 + 4{\times}1$	$= 16 + 4$
25	0001 1001	19	$= 1{\times}16^1 + 9{\times}16^0$	$= 1{\times}16 + 9{\times}1$	$= 16 + 9$
30	0001 1110	1E	$= 1{\times}16^1 + 14{\times}16^0$	$= 1{\times}16 + 14{\times}1$	$= 16 + 14$

For clarity, a non-base 10 number should have the base subscripted after the number. For example, to show the difference between 100 in base 10 and 100 in base 2 (which represents 4), the base 2 number should be written as 100_2.

Unicode

Every letter of an alphabet (Latin, Japanese, Cherokee, and so on) and symbols of every culture (=, @, ½, and so on) have been given a representation in a digital code called Unicode. *Unicode* uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol. For example, the uppercase letter V is Unicode 00000000 01010110, which can be thought of as the base 10 number 86 (86_{10}). Lowercase v has a separate code of 00000000 01110110, or 118_{10}. Refer to Chapter 6 for additional Unicode symbols. Appendix B also contains additional symbols.

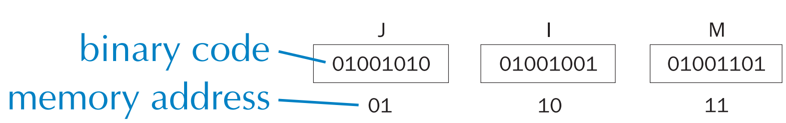
1.13 Storing Data in Memory

Storage Media

The capacity of storage media varies. For example, a diskette has a storage capacity of 1.44 MB, a CD has a storage capacity of 650 MB, and a DVD has a storage capacity of over 4GB.

Computer memory, file sizes, and storage device capacities are measured in bytes. For example, a computer might have 128MB of RAM. In computers and electronics *MB* stands for *megabytes* where mega represents 2^{20} or 1,048,576 bytes and *GB* stands for *gigabytes*, which is 2^{30} or 1,073,741,820 bytes. Simple files, such as a text document, can be measured *kilobytes*, for example 256K. The *K* comes from the word *kilo* and represents 2^{10} or 1,024. Therefore, a 64K file uses 65,536 bytes (64×2^{10}) of storage.

Data stored in memory is referred to by an address. An *address* is a unique binary representation of a location in memory. Therefore, data can be stored, accessed, and retrieved from memory by its address. For data to be addressable in memory, it must usually be at least one byte in length. For example, to store JIM in memory each character is converted to Unicode and stored in two bytes of memory with each memory location designated by its address:



Because JIM is a character string, it will probably be stored in adjacent memory addresses.

word

Bits grouped in units of 16 to 64 (2 to 8 bytes) or more are called *words*. Data stored in a word is also located by an address. The size of a word depends on the computer system.

overflow error

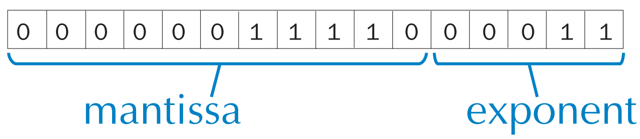
The binary representation of an integer number is usually stored in four bytes of memory. Because an integer is stored in four bytes, the range of integers that can be stored is –2,147,483,648 to 2,147,483,647. An *overflow error* occurs when the number of bits that are needed to represent the integer is greater than the size of four bytes.

real numbers

mantissa

exponent

Real numbers, also called *floating point numbers*, are numbers that contain decimal points. The binary representation of a real number is usually 4 to 8 bytes of memory. The binary number 111.10 is equivalent to the real decimal number 7.5 and is stored in memory as the binary number 0.11110×2^3. In this form, the bits that represent the *mantissa* (fractional part) are stored in one section of a word and the exponent, in this example 3 (11_2), is stored in another section of the word:



roundoff error

The overflow problem discussed for integers can also occur in real numbers if the part of the word storing the exponent is not large enough. A *roundoff error* occurs when there are not enough bits to hold the mantissa.

1.14 The Social and Ethical Implications of Computers

information age

The society in which we live has been so profoundly affected by computers that historians refer to the present time as the *information age*. This is due to the computer's ability to store and manipulate large amounts of information (data). Because of computers, we are evolving out of an industrial and into an information society. Such fundamental societal changes cause disruptions which must be planned for. For this reason it is crucial that we consider both the social and ethical implications of our increasing dependence on computers.

netiquette

By ethical questions we mean asking what are the morally right and wrong ways to use computers. For example, when working on a network, users should follow a certain etiquette referred to as *netiquette*:

- Do not attempt to access the account of another user without authorization.
- Do not share your password, and change it periodically.
- Use appropriate subject matter and language, and be considerate of other people's beliefs and opinions. This is especially important when posting messages that will be sent to every user on the network.

privacy

A serious ethical issue associated with computers is the invasion of privacy. Every time you use a credit card, make a phone call, withdraw money, reserve a flight, or register at school a computer records the transaction. These records can be used to learn a great deal about you—where you have been, when you were there, and how much money you spent. Should this information be available to everyone? To protect both the privacy of an individual and the accuracy of data stored about individuals, a number of laws have been passed.

The **Fair Credit Reporting Act of 1970** deals with data collected for use by credit, insurance, and employment agencies. The act gives individuals the right to see information maintained about them. If a person is denied credit they are allowed to see the files used to make the credit determination. If any of the information is incorrect, the person has the right to have it changed. The act also restricts who may access credit files to only those with a court order or the written permission of the individual whose credit is being checked.

The **Privacy Act of 1974** restricts the way in which personal data can be used by federal agencies. Individuals must be permitted access to information stored about them and may correct any information that is incorrect. Agencies must insure both the security and confidentiality of any sensitive information. Although this law applies only to federal agencies, many states have adopted similar laws.

The **Financial Privacy Act of 1978** requires that a government authority have a subpoena, summons, or search warrant to access an individual's financial records. When such records are released, the financial institution must notify the individual of who has had access to them.

The **Electronic Communications Privacy Act of 1986** (ECPA) makes it a crime to access electronic data without authorization. It also prohibits unauthorized release of such data.

The **Electronic Freedom of Information Act of 1996** requires federal government agencies to make certain agency information available for public inspection and is designed to improve public access to agency records.

The **Safety and Freedom through Encryption Act of 1999** (SAFE) gives Americans the freedom to use any type of encryption to protect their confidential information. It also prohibits the government from monitoring people's communications without their knowledge or consent.

1.15 Protecting Computer Software and Data

Because computer software can be copied electronically, it is easy to duplicate. Such duplication is usually illegal because the company producing the software is not paid for the copy. This has become an increasingly serious problem as the number of illegal software copies distributed through *piracy* has grown. Developing, testing, marketing, and supporting software is an expensive process. If the software developer is then denied rightful compensation, the future development of all software is jeopardized.

piracy

Software companies are increasingly vigilant in detecting and prosecuting those who illegally copy their software. Persons found guilty of using illegally copied software can be fined, and their reputation damaged. Therefore, when using software it is important to use only legally acquired copies, and to not make illegal copies for others.

Another problem that is growing as computer use increases is the willful interference with or destruction of computer data. Because computers can transfer and erase data at high speeds, it makes them especially vulnerable to acts of vandalism. These acts are usually illegal and can cause very serious and expensive damage. The Electronic Communications Privacy Act of 1986 specifically makes it a federal offense to access electronic data without authorization.

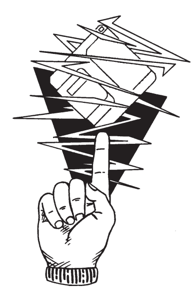
virus

A *virus* is a program that is designed to reproduce itself by copying itself into other programs stored on a computer without the user's knowledge. Viruses have varying effects, such as displaying annoying messages, causing programs to run incorrectly, and erasing the contents of the hard drive. Precautions need to be taken to avoid getting a virus:

Worm

A worm is a type of virus that can reproduce itself and use the memory of a computer, but it cannot attach itself to a program.

- Invest in antivirus software. Antivirus software will detect many types of viruses by scanning incoming e-mail messages before they are opened. If a virus is detected, the software will display a warning and try to remove the virus.
- Update the antivirus software frequently. New viruses are continually being created and new virus definitions must be downloaded on a regular basis in order for the antivirus software to be effective.
- Many computer viruses have been associated with e-mail attachments. Therefore, always save an attachment file and then virus-check the file before opening it. This precaution should be taken for all messages from known and unknown sources, since many viruses target address books and fool users into thinking the e-mail is from someone familiar.
- Virus scan a diskette before opening files stored on the diskette.



Contaminated diskettes are one way that viruses are spread from computer to computer

1.16 The Ethical Responsibilities of the Programmer

It is extremely difficult, if not impossible, for a computer programmer to guarantee that a program will *always* operate properly. The programs used to control complicated devices contain millions of instructions, and as programs grow longer the likelihood of errors increases. A special cause for concern is the increased use of computers to control potentially dangerous devices such as aircraft, nuclear reactors, or sensitive medical equipment. This places a strong ethical burden on the programmer to insure, as best as he or she can, the reliability of the computer software.

As capable as computers have proven to be, we must be cautious when allowing them to replace human beings in areas where judgement is crucial. As intelligent beings, we can often detect that something out of the ordinary has occurred which has not been previously anticipated and then take appropriate actions. Computers will only do what they have been programmed to do, even if it is to perform a dangerous act.

Chapter Summary

The earliest computing devices were mechanical and were often unreliable. The advent of electricity brought about electromechanical machines, and later first generation computers that used vacuum tubes. The architectural design of computers changed with the idea of a machine that could perform many different tasks by simply changing its program. With the development of the transistor came second generation computers that were much smaller and faster. Programming languages were developed so programmers could write English-like instructions. Third generation computers used integrated circuits. Fourth generation computers include an entire CPU on a single chip. In the 1980s, object-oriented programming (OOP) evolved out of the need to better develop complex programs in a systematic, organized approach.

The physical components of the personal computer are called hardware. The personal computer accepts data from an input device. A personal computer becomes much more versatile when other devices such as printers and scanners are added. These devices are sometimes called peripheral devices. A scanner in an input device that uses a laser to create a digital image from artwork. Output devices display or store processed data.

The base unit of a personal computer contains many components including the CPU, ROM, RAM, SRAM, a motherboard, the data bus, the address bus, and the control bus. A CPU directs the processing of information throughout the computer. Within the CPU is the ALU, which is the basis of the computer's decision-making power. The speed at which a CPU can execute instructions is determined by the computer's clock rate. The clock rate is measured in megahertz (million of cycles per second). Since RAM storage is temporary, data is stored on a type of storage media, such as a floppy diskette, a hard disk, a zip disk, or a CD-R.

Personal computers also contain software that instructs the computer what to do. Operating system software is run automatically when the computer is turned on and enables the user to communicate with the computer. Applications software is written by programmers to perform a specific task.

A network is a combination of software and hardware that works together to allow computers to exchange data and to share software and devices, such as printers. Common network size classifications are LAN (Local-Area Network) and WAN (Wide-Area Network). LAN topologies include bus, star, and ring.

Network architecture includes the type of computers on the network and determines how network resources are handled. Two main types of network architecture are called client/server and peer-to-peer.

The electrical circuits of an IC have one of two states, off or on. Therefore, the binary number system is used to represent the two states: 0 for off and 1 for on. Each 0 or 1 in binary code is called a bit and a 8-bit unit is called a byte.

Our most familiar number system is the decimal or base 10 system. The binary number is a base 2 system and the hexadecimal system is base 16.

Every letter of an alphabet and every symbol of a culture have been given a representation in a digit code called Unicode. Unicode uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol.

Computer memory, file sizes, and storage device capacities are measured in bytes. In computers and electronics MB stands for megabytes, GB stands for gigabtyes, and K stands for kilobytes.

The binary representation of an integer number is usually stored in four bytes of memory. An overflow error occurs when the number of bits that are needed to represent the integer is greater than the size of two bytes. Real numbers are numbers that contain decimal points and the binary representation of a real number is usually stored in 4 to 8 bytes of memory.

The society in which we live has been so profoundly affected by computers that historians refer to the present time as the information age. The increasing dependence on computers requires examining the social implications of our increasing dependence on computers. For example, when working on a network users should follow a certain etiquette referred to as netiquette. Ethical issues related to computer use are privacy, piracy, viruses, and the reliability of software.

Vocabulary

Ada A high-level programming language that supports real-time applications.

Address A unique binary representation of a location in memory.

Address bus Carries memory addresses that indicate where the data is located and where the data should go.

ALU (Arithmetic Logic Unit) The part of the CPU that handles arithmetic and logic operations.

Applications software Commercially produced programs written to perform specific tasks.

Base unit Unit where the CPU, memory, and hard disk drive is housed.

BASIC A high-level computer language developed by John Kemeny and Thomas Kurtz.

Binary number system Number system used by modern computers—uses only digits 0 and 1. Also called Base 2.

Bit (BInary digiT) A single 0 or 1 in binary code.

Bus A set of circuits that connect the CPU to other components.

Bus Topology Connects each node of a network to a single shared communication cable called a bus.

Byte A group of 8 bits.

Client/Server Network A group of computers, called clients, connected to a server.

Clock rate The speed at which a CPU can execute instructions.

COBOL A high-level programming language designed by Grace Murray Hopper.

Computer An electronic machine that accepts data, processes it according to instructions, and provides the results as new data.

Control bus Carries control signals.

CPU (Central Processing Unit) A component inside the base unit that processes data and controls the flow of data between the computer's other units.

Data bus Transfers data between the CPU, memory, and other hardware devices on the motherboard.

Fortran A high-level programming language developed by John Backus.

GB (gigabyte) 1,073,741,820 bytes.

Hardware The physical components of the personal computer.

Hexadecimal system Number system based on 16 digits. Also called base 16.

High-level programming language A programming language that uses English-like instructions.

Information age A term used by historians to refer to the present time.

Input device Used by the computer to accept data.

IC (Integrated Circuit) Also called a chip. A silicon wafer with intricate circuits etched into its surface and then coated with a metallic oxide that fills in the etched circuit patterns.

K (kilobyte) 1,024 bytes.

Local Area Network (LAN) A network that connects computers within a small area.

Machine language Instructions in binary code (0s and 1s).

Mainframe Computer system that is usually used for multiuser applications.

Mantissa The fractional part of a

MB (megabyte) 1,048,576 bytes.

Memory A component inside the base unit that stores data electronically.

Microcomputer A computer that fits on a desktop and uses a microprocessor.

Microprocessor An entire CPU on a single chip.

Motherboard The main circuit board inside the base unit.

Mouse An input device from which the computer can accept information.

Nanosecond One billionth of a second.

Netiquette Network etiquette.

Network Allows computers to exchange data and to share applications software and devices.

Network Architecture Includes the type of computers on the network and determines how network resources are handled.

Network interface card A circuit board in the base unit of a networked computer.

Node A device that is connected to the network and is capable of communicating with other network devices.

Operating system software Software that allows the user to communicate with the computer.

Output devices Display or store processed data.

Overflow error An error that occurs when the number of bits that are need to represent the integer is greater than the size of four bytes.

Personal Computer A small computer employing a microprocessor. See also microcomputer.

Peer-to-Peer Network A group of computers that share responsibilities and resources equally without a server.

Peripheral device A device attached to a personal computer.

Piracy The illegal copying of software.

Program List of instructions written in a special language that the computer understands.

RAM (Random Access Memory) Temporary memory where data and instruction can be stored.

Read Accessing data from a storage medium.

Real numbers Numbers that contain decimal points. Also called floating point numbers.

Ring Topology Each node of a network is connected to form a closed loop.

ROM (Read Only Memory) Data that is a permanent part of the computer and cannot be changed.

Roundoff error An error that occurs when there are not enough bits to hold the mantissa.

Scanner Uses a laser to create a digital image from artwork.

Software Instructions stored as electronic data that tells the computer what to do.

SRAM (Static Random Access Memory) High-speed memory referred to as cache.

Star Topology Connects each node of a network to a hub, which is a device that joins communication lines at a central location on the network.

Storage media Used to store data.

Terminal A keyboard and monitor used to communicate with a mainframe.

Topology The logical arrangement of the nodes on a network. A node is a device, such as a computer or printer that is connected to the network and is capable of communicating with other network devices.

Transistor An electronic device that replaced the vacuum tube making computers smaller and less expensive and increasing calculating speeds.

Unicode A digital code that uses a set of sixteen 1s and 0s to form a 16-bit binary code for each symbol.

Virus A program designed to reproduce itself by copying itself into other programs stored on a computer without the user's knowledge.

Word Bits grouped in units of 16 to 64 or more.

Write Storing data on a storage medium.

Review Questions

Sections 1.1 — 1.4

1. Briefly describe the Pascaline and explain what mathematical operation it was designed to perform.

2. a) What mathematical operations was the Stepped Reckoner supposed to perform?
   b) Why was it unreliable?

3. What did Ada Byron mean when she said that the Analytical Engine could never "originate anything"?

4. a) For what purpose did Herman Hollerith invent his tabulating machine?
   b) What were punched cards used for in the tabulating machine?

5. Why wasn't the Mark 1 considered a computer?

6. What number system did the Atanasoff-Berry Computer use?

7. For what purpose was the ENIAC originally designed?

8. What is a computer?

9. In what way did Alan Turing and John von Neumann improve upon the design of the ENIAC?

10. a) What is a program?
    b) What is machine language?
    c) List the first three computers designed to use a stored program.

11. Why was the invention of the transistor important to the development of computers?

12. How did the use of magnetic tape improve the performance of computers?

13. a) What is a high-level programming language?
    b) Who designed COBOL?
    c) List three high-level programming languages.
    d) Why was object-oriented programming developed?
    e) List two object-oriented programming languages.

14. Explain what integrated circuits are and why they have been important in the development of computers.

15. a) What is a mainframe?
    b) What is the usual way for a person to communicate with a mainframe?

16. Why was the invention of the microprocessor important to the development of computers?

17. List some of the advantages of a microcomputer compared with the ENIAC or UNIVAC.

Sections 1.10 — 1.17

18. a) What is hardware?
    b) What are input and output devices used for?
    c) What is a peripheral device?

19. List and describe 5 components found inside the base unit.

20. List 3 examples of storage media.

21. Describe the flow of data between the components of a computer.

22. In what way was the design of Babbage's Analytical Engine similar to the modern computer?

23. a) What is the difference between operating system software and applications software?
    b) What is another name for software?

24. What is a network?

25. List four benefits of using a network.

26. a) What are the two most common size classifications for networks?
    b) What size classification is used to connect devices over large geographical distances?

27. a) What does network architecture include?
    b) Describe clients and servers.

28. a) What is topology?
    b) What is a node?
    c) What topology uses a hub?
    d) What topology connects each node to form a closed loop?

29. Why was the binary number system adopted for use in computers?

30. Explain what a bit and a byte are.

31. a) What is the decimal equivalent of 111_2?
    b) What is the decimal equivalent of $2C_{16}$?

32. What is Unicode?

33. a) How many bytes of data can 32 MB of RAM store?
    b) How many bytes of data can a 3 GB hard drive store?

34. What are bits grouped in units of 16 to 64 or more called?

35. a) When would an overflow error occur?
    b) When would a roundoff error occur?

36. What are real numbers?

37. What is meant by the information age?

38. List two examples of netiquette.

39. How can computers be used to invade one's privacy?

40. List and then explain three laws passed to protect an individual's privacy.

41. What is piracy?

42. List three precautions that can be taken to avoid getting a virus.

43. a) What ethical responsibilities does a programmer have when writing a program that will impact human lives?
    b) Can the programmer absolutely guarantee that a program will operate properly? Why?

Exercises

Note that the exercises below require written information. If a word processor is used, be sure to use an appropriate header, footer, and file name.

Exercise 1

Expand on the information presented in this chapter by researching one of the following topics:

- The History of Computers
- Individuals in the Computer Industry
- The History of a Computer Company
- Current Mainframe Computers

a) Use the Internet, magazines, and books to find at least three sources of information.

b) Write a two page report that summarizes your research.

c) On a separate sheet, titled References, cite each source.

Exercise 2

In this exercise you will research your classroom computer and network by answering a series of questions.

a) What type of input devices are attached to your computer?

b) What peripheral devices are attached to your network?

c) What visual output device is attached to your computer?

d) List the storage media that can be used with your computer.

e) How much RAM does your computer have?

f) What is the computer's clock rate?

g) List an application software program available on your computer.

h) Is your computer network a LAN or a WAN?

i) What type of topology is used in your computer network?

j) What network operating system is used?

k) What kind of Internet connection does your network use?

Exercise 3

In this exercise you will research the cost of purchasing a personal computer.

a) Use the Internet, magazines, and newspapers to find advertisements for three similar personal computers.

b) Summarize the features of the three computer systems. Along with the technical specifications, be sure to note warranty and service information.

c) Write a one paragraph conclusion that explains what computer system would be the best buy.

Exercise 4

In this exercise, you will research the computer courses in your school to find out what software and what programming languages are taught in what courses.

a) Obtain a school calendar, talk to teachers, or use the school's web site to find course information.

b) List all the computer courses available in the school.

c) For each course listed in part (b), list what software or what programming language is taught in the course.

d) For the programming courses, note which courses teach an object-oriented programming language.

Exercise 5

In this exercise, you will research a social or ethical issue associated with computer use, such as privacy, piracy, or viruses, to find real-life examples of how these issues have impacted companies or individuals.

a) Use the Internet, magazines, and books to find at least three sources of information.

b) Write a two page report that summarizes your research.

c) On a separate sheet, titled References, cite each source.